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CERTAIN ADVANCES IN METEORITICS

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ABSTRACT

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The author describes meteorite discoveries in the past. Hypotheses are presented and analyzed regarding the origin of meteorites. Tektites are discussed in great detail. The author concludes that a more detailed study is necessary due to the complexity of the problem.

Author

There is no doubt that the study of meteorites is constantly /5 * acquiring greater importance for an understanding of the structure and the evolution of cosmic matter in general, and the origin of our solar system in particular. However, the manifold and fine characteristics of meteoric matter are still far from being studied, and a detailed study of them is a matter for the future.

It is generally assumed that the Widmanstätten structure of iron meteorites results from the transformation of a high-temperature gamma phase into an alpha phase during cooling, or into a mixture of both phases. The temperature at which this transformation begins depends on the nickel content, and can be estimated.

In 1951, Fogel[1] postulated a somewhat different model for the

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* Note: Numbers in the margin indicate pagination in the original foreign text.

formation of the Widmanstätten structure. He assumed that the alpha phase was stable even in a liquid state in the presence of a small amount of phosphorus (in tenths of a percent). But even he assumed that such meteorites cool slowly within the temperature range 600-400°C.

It is my opinion that stony meteorites have a much more diverse structure, and in addition to that are much more difficult to interpret. They have a particularly great variety of chemical elements with different isotopes. Metallic particles which occur in stony meteorites also consist of kamacite and taenite, and very frequently - as Urey (Ref. 1) and others have observed - both these types of particles are separated from each other and are completely surrounded by silicates. A study of such samples shows that a powerful crushing process must have once broken up the initial mass into a great many small particles, which then reformed into a compact mass. In actuality, sometimes fragments of one type of meteorite are found within another type, belonging to a completely different group - for example, as Val', Urey and others indicated, finding a black chondrite within a white achondrite   Cumberlend Falls.

Chondrites are of very great interest. Chondrules, which sometimes are found within them, are glass-like in appearance, and contain small particles of metal, as if they were formed during the solidification of liquid drops - as Sorbi assumed in 1864. As is known, other chondrules have a crystalline structure, and look as though they were formed from the crystallization of liquid drops. The simultaneous presence of liquid drops and particles of nickelous iron makes the

formation of such a meteorite even more enigmatic. Apparently, drops of silicates and metallic particles were formed separately, and then were combined together. It is not clear whether this /6
occurred in a vast cloud over the surface of some primary object, as the result of numerous collisions.

In addition, the presence of diamonds in meteorites poses a particular problem, since the formation of diamonds requires a rather high pressure. As is known, the presence of diamonds was first established by Yerrfeyev and Lachinov in 1888 in the stony meteorite Novyy Urey (Ref. 2).

The fact that many meteorites are penetrated by a network of veins, ranging in thickness from a fraction of a centimeter up to hundredths of a millimeter, represents a special problem. The narrowness of the veins and the glass-like nature of the substance contained in them in anorthite crystals in eucrites seem to point to very brief and only local melting with subsequent, rapid cooling. The veins have the composition of the substance comprising them and also the color: in some cases they are colorless, and in other cases they are dark. They are frequently accompanied by finely-pulverized particles of troilite, usually in the form of drops contained in a glass-like silicate medium, which seems to point to a high formation temperature. However, at a distance of several millimeters, crystalline grains of kamacite are sometimes encountered (Ref. 3) with Neumann lines which cannot be retained above 1000°K when heated, and then only for a few seconds.

It can be seen from the statements above that an interpretation of the structure of meteorites is very difficult, while a study of this structure encounters even greater difficulties. Therefore, it is not surprising that no definite decision has been reached regarding the origin of meteorites. There is apparently no doubt that meteorites were formed by the disintegration of asteroidal bodies, and that this disintegration occurred with the consumption of only a small amount of energy, without intense heating and without any change in the internal structure of the parent substance. However, these so-called asteroids had a very complex internal structure, which was only discovered when meteorites fell into our hands and must have been the result of long, complex processes. There are differing opinions at the present time with respect to these processes.

Thus, for example, Ringwood and Lovering (Ref. 4) have formulated the hypothesis that the parent body had an intermediate size between the earth and the moon. But in a body of this size, the central nucleus would have to be liquid during any period of its existence, in order that the metallic portion could be separated from the silicate portion. However, Urey (Ref. 5) showed that a body the size of the moon could not be cooled to the requisite low temperature throughout the entire lifetime of the solar system. If one takes into account the radioactive heating from uranium, thorium, and potassium 40, it can be shown - as he points out - that the radius of the parent body could not exceed 1000 km. In addition, it is completely incomprehensible how a body the size of a planet could be split into individual parts. If this occurred during the collision of bodies, having similar masses, at cosmic velocities, then the heating temperature would have to reach tens of thousands of degrees, or even more.

Urey advanced another hypothesis for the origin of meteorites, assuming that these bodies were formed in at least two consecutive generations (Ref. 6). In his opinion, the first bodies were formed at comparatively low temperatures, and contained a large amount of thermodynamic, unstable compounds, as well as free radicals. Exothermic chemical reactions could take place in such bodies. If a body were sufficiently large (according to the estimate made by Urey, they must be approximately the size of the moon) and if there /7 were no explosive dispersion of the substance - i.e., the entire substance remained in the same bodies - then local chemical reactions, fusions, and the separation of the metallic and silicate phases could occur. This entire process could lead to the formation of reservoirs of pure silicate or of metal several or more meters in size. The substance for achondrites and iron meteorites could be formed in this way. In the opinion of Urey, these reactions could first occur on the surface of such objects, and then - as continuous growth took place - at rather large depths, and the conditions were created for the formation of diamonds from graphite. Widmanstätten figures could thus be gradually formed at a temperature within the object which remained at about 450°C for a long period of time. In addition, Urey assumes that such primary bodies, colliding with each other, broke up into sections which gradually formed bodies having asteroidal dimensions - the immediate parents of the meteorites existing in them. The formation of such secondary bodies occurred at comparatively low temperatures, and they produced a substance - which had already been developed previously - with all of their characteristics. At a later time, new collisions broke up the secondary objects, and the meteorites which we know were formed.

This theory has several advantages, since it explains several peculiarities of meteorites, but it must introduce large masses of primary bodies in order to explain the formation of diamonds. However, the presence of diamonds in meteorites is a rather rare phenomenon, and possibly the grains of diamonds are formed not in primary bodies, but rather represent a secondary phenomenon. They may possibly be formed during later collisions, when significant local pressures arise, or even during impacts on the surface of the earth - similarly to the formation of koesite from quartz. In addition, it should be noted that the recent discovery of radiogenic xenon 129 in many chondrites (Ref. 7) indicates that such radiogenic substances as iodine 129, plutonium 244, and possibly beryllium 10, aluminum 26, and several others - which have a very small half-life and, consequently, a very large liberation of energy - must have existed in the past. However, the possible role of such elements - which have been completely exhausted by now -

depends on how long ago these elements could be formed in the solar system with respect to the formation of the planets, and consequently when the chemical elements could be formed which served as the basis for the subsequent formation of entire complexes of bodies in the portion of the galaxy which they occupied.

Certain considerations can be formulated in opposition to Urey's hypothesis. For example, this includes the fact that many polymictite meteorites are, in all probability, formed from sections whose structure is completely diverse, but which are very similar in terms of their chemical composition. Such a phenomenon is only slightly probable if such meteorites result from the entirely random accumulation of composite fragments of primary bodies. Urey also assumes that achondrites were formed in primary bodies before the synthesis of chondrites, but some data appear to refute this supposition.

In line with these considerations, it can be stated that - according to Anders - processes which are similar to volcanic eruptions can even occur in comparatively small bodies, which are similar to asteroids. These processes will take place as the result of chemical reactions without the participation of water - for example, between iron sulfide (FeS), quartz (SiO_2), and carbon (C). Iron can thus be separated out in pure form, as well as SiS, and carbon monoxide CO.

A reaction such as $FeS + SiO_2 + 2C = Fe + SiS + 2CO$ is used in practice for deriving sulphur from steel, and requires a temperature of about 1800°K. /8

A reaction such as $2FeS = 2Fe + S_2$ can also take place in meteorites, but it requires a higher temperature. If such reactions take place at the boundary between the iron nucleus and the mantle, then gases are liberated which can reach a rather high pressure and will transfer the melted material to the surface of the body. It may be the case that local heating takes place in this way in the initial substance, which would explain certain structural characteristics of meteorites.

It can be seen from the statements given above that the origin of meteorites has not been fully explained up to the present time. The difficulties are aggravated by the fact that the cosmic age of stony and iron meteorites is completely different, as a rule. This age represents the period of time in which a meteorite - after being separated from the parent body which is much larger - rotates around the sun similarly to a small planet, and is subjected to the bombardment by cosmic rays and other influences. It is thus assumed - which is now considered to be absolutely valid - that the intensity of cosmic rays has remained almost unchanged, at least for hundreds of millions of years. However, there is a certain amount of uncertainty regarding the effect produced by the meteorite substance being screened by external layers of its initial mass, up until it enters the terrestrial atmosphere. As is known, the content of helium 3 and the heavy hydrogen-tritium isotope is used to determine the cosmic age. It is assumed that the total rate at which the first isotope is formed is twice as large as the second. As a result, it has been found that the age of stony meteorites is at least one order of magnitude smaller than that of iron meteorites. Several authors have thus drawn the conclusion that these varieties of meteorites come to us from different regions in cosmic space.

Thus, for example, the cosmic age of the achondrite Abee is 13 million years; Elenovki- 30 million years; Kunashak - 4 million years in all; and only Norton County has an age of 230 million years. On the other hand, several iron meteorites have cosmic ages which exceed millions of years - for example, Norfolk, Pará de Minas, Mount Ayliff, Thunda. Only the Sikhote-Alinskiy iron meteorite is comparatively young, as an individual body in the solar system; its age is approximately 170 million years. Such a difference cannot be a matter of accident. The reason for this can lie in the fact that stony and iron meteorites have a different origin - the former, in the opinion of Urey, could have been ejected from the surface of the moon toward us, and the latter could have come from the asteroidal zone. If, however, it is assumed that all meteorites have the same origin - which seems much more natural - then the conclusion must be drawn that for various reasons stony meteorites have an abnormally small amount of helium 3 and tritium isotopes. Either these gases are generally not completely retained in them, or the initial surface layers of stony meteorites - which have previously screened their internal sections from bombardment by cosmic rays - were "stripped off" comparatively rapidly under the influence of different cosmic bombardments. It is difficult to say how rapidly this process could take place, but the required rate for such "stripping" would have to be approximately 30 cm every tens of millions of years. The rate at which such a process occurs can be approximately determined by observing meteors, if the lifetime of such small particles in the solar system can be estimated and if it is possible to trace the development of their internal structure. In this connection, it can be pointed out, for example, /9 that the collection of cosmic matter, which was made by the rocket Aerobee 150 (Ref. 8) at altitudes between 116 and 168 km above sea level, yielded the following results. About 16% small pellets, 72% irregular fragments with sharp edges, and about 12% particles having an extremely irregular form, which were nappy (flaky) in nature (7 pieces per 1mm^2, on the average) adhered to specially-constructed screens which were located in the nose of the rocket. According to the estimates of Siberman and Khemenueya, in 90% of the cases these particles were smaller that 1 micron. It has been established for a long period of time that, as a rule, meteors comprising different meteoric streams also have a very small mean particle density, which reflects the porosity of their structure. As is known, Wood and others have made theoretical calculations of cosmic erosion on the surface of solid objects in the solar system.

In this connection, it can be noted that a photometric study of different bodies in the solar system which have no atmosphere - for example, the moon or asteroids - indicates that their surfaces have unusual microstructural properties. For example, the moon looks to us like a flat disc with sharply-defined edges, whose brightness is identical with the center of the disc - if the presence of dark spots, the so-called seas, is overlooked. Each element on the lunar surface is brightest during the full moon - i.e., during a phase angle which exactly equals zero. This phase curve has a characteristic point for the moment of the full moon, so that during the phase equaling zero it is possible to construct two tangents which are inclined with respect to both of its sides. The observations of Gerel's and V. G. Teyfel' at the Astrophysical Observatory of the Kazakh SSR Academy of Sciences in Alma-Ata, show this effect is more readily apparent in the case of asteroids.

With respect to the moon, this effect has been known for a long period of time, and various authors have tried to reproduce this structure on the surface of a body being studied in laboratory experiments. This body was illuminated, and observed at different angles in order to obtain the phase curve. However, it was found that it was not possible to reproduce the phase curve which was observed in practice, no matter what the degree of unevenness or irregularity for which the effect of partial shading was particularly well defined, with the phase angle differing from zero. Apparently, it must thus be assumed that the microstructure of all such bodies which have no atmosphere - to which meteorites belong - has a different, branched form while they are traveling in interplanetary space, and represent different grains which adhere to each other and which have a certain electrostatic charge. In the case of the moon or asteroids, these grains remain in contact with each other due to the general force of gravity, but at the same time they tend to be repelled by their similar charges. The surface of asteroids is actually subjected to interplanetary erosion throughout their lifetime, and therefore they can have sharply-defined characteristics in this respect. On the lunar surface - where there is a different type of evolutionary processes and where individual sections have a different age - this effect is less pronounced on the average. Meteorites, which have traveled for millions of years in interplanetary space, cannot retain matter which is pulverized by such bombardments, and they form an extremely fine dust, which comprises the over-all cosmic dust background of interplanetary space. We would like to point out that, according to recent data (the estimates of Hawkins [Ref. 9] and others), the amount of meteors having an asteroidal - i.e., a purely meteoritic-origin is approximately several percents of the total number of meteors which are definitely related to comets and /10 which represent their decomposition product.

Thus, we cannot deny the possibility of comparatively rapid deterioration and exfoliation of the outer layers of stony meteorites into surrounding space. Due to this process, in the final analysis these meteorites must be smaller than iron meteorites, and to a lesser extent must be able to accumulate decomposition products due to the effect of primary cosmic rays.

It is evident that when a meteoritic mass travels through the terrestrial atmosphere its surface undergoes considerable melting, with the total loss of its initial microstructure, which we mentioned above. Traveling hundreds of kilometers in the form of an incandescent bolide, the meteor comes to a stopping point. Here, the resistance stress increases to a maximum, and the meteorite partially disintegrates into several individual fragments. As they fall to the earth's surface, they cover an elliptical area of several tens of square kilometers. In this respect, iron and stony meteorites behave in the same way. This was the case with the fall of the well-known Sikhote-Alinskiy iron meteorite, whose fragments covered an area of 1.6 km^2. Due to their irregular form, such meteoritic masses undergo strong deceleration in the atmosphere. The behavior of the largest individual lump of of the Sikhote-Alinskiy fall was particularly characteristic. It weighed 1750 kg, and was found in the rear section of a scattering ellipse far to the side of the meteorite trajectory. Due to its irregular, flat form, it underwent particularly strong deceleration and traveled far to the side.

Similarly, during the recent fall of the sulphur chondrite Bruderheim, which occurred on March 4, 1960 (Ref. 10), the detonating bolide was seen above 300 km, and the noise produced by it was heard over an area of about 4000 km^2. The bolide had an initial velocity of about 12 - 16 km/sec. The scattering ellipse was covered by numerous fragments; the over-all weight was approximately 300 kg, while the largest fragment weighed 31 kg. Five hundred other pieces which were found weighed less than 100 g each. The scattering ellipse dimensions were 5.6 x 3.6 km, and the largest masses usually fell in its forward section. A large lump of the Sikhote-Alinskiy meteorite represented an exception to this, due to its irregular form and due to the exceptionally large deceleration related to this.

The fall of enormous meteoritic masses is invariably accompanied by the formation of craters and holes. At the present time, the only known craters in the USSR are being studied at the island of Saarema (Ezel'), which were previously studied by Reynval'd. Some data on the formation mechanism of meteoritic craters were obtained during the explosions of atomic bombs - perhaps the only useful application of these experiments.

The formation mechanism of meteoritic craters was examined by Shoemaker, for supersonic velocities of the falling meteorite (Ref.11). In particular, he performed a theoretical investigation of a fall at the velocity of 15 km/sec, which apparently corresponds to the formation of the Arizonskiy crater. The meteorite fell onto the ground, contracted and melted rocks in front of it, and was contracted itself. Within the meteorite, a shock wave was propagated. An expansion wave was reflected back through the meteorite, and it expanded - but it moved at a decreased velocity of about 5 km/sec. A large portion of its energy was thus transmitted to the contracted, melted rocks in front of the meteorite. The contracted portions of the melted rock and the meteorite were thrust to the side, along the path through which it passed. The shock wave was propagated to the side of the depression, the depression expanded, /11
and the melted mass and fragments were thrust outwards. If a total

energy of 1.7 megatons and a velocity - as was indicated - of 15 km/sec are assumed, a mass is obtained for the meteorite of 63,000 tons. For a density of 7.85 g/cm^3, the diameter of this mass must be about 24.8 m. In this connection, it can be recalled that in the case of the Sikhote-Alinskiy fall barely more than 100 tons of iron mass fell on the surface on the whole, in a pulverized state and at a velocity which did not exceed 600 m/sec. Nevertheless, a large amount of craters was formed in the rock of the Sikhote-Alinskiy mountain range. The results obtained by Shoemaker are therefore completely plausible, because he investigated a single large mass moving at a velocity which was far from exceeding the velocity of sound.

According to present estimates, the Arizonskiy crater was formed about 25,000 years ago, and has been fairly well retained to the present due to its unusual dimensions, and also because it is located in a desert region. It is interesting to recall that several years ago its meteoritic nature was questioned. In passing, its clearly-expressed rectangular form, and not rounded, was pointed out, as well as the absence of buried meteoritic masses within it. Somewhat later, numerous meteoritic masses were found in the immediate vicinity of the crater, weighing up to several hundreds of kilograms, so that there was no question of its meteoritic nature. In addition, other indisputable indications of its meteoritic nature have recently been established in the observed damage to the relief - the so-called shock cones and the presence of a superhard modification of quartz-koesite.

Cosmic falls at a velocity on the order of 15 km/sec can produce brief pressures in millions of atmospheres. Normal volcanic eruptions are accompanied by pressures of only hundreds of atmospheres - a comparatively negligible amount. Thus, a long time after the disappearance of a crater which has been formed, and even after the disappearance of the falling, pulverized fragments of the initial meteoritic mass, the characteristic signs still remain which are produced by these unusually intense and sudden shock waves. The shock cones indicated above are the best example of this. The sections of mountains, which are characterized by an unusual conical form and by folds going out from one point, as from an apex, are called by this name. They range in size from several centimeters to several meters. During the impact, such a shock cone is broken up into similar cones which are smaller. These formations are most frequently encountered among deposits of limestone or of sand, but they are also encountered in any rock. They were first discovered in Southern Germany in the Shteinheim Basin.

Dietz (Ref. 12) carried out particularly detailed searches for and studies of such formations; he found several shock cones in the USA. In the State of Indiana, he found several such formations with an age of 400 million years. As a rule, shock cones are oriented at right angles to the stratification plane of sedimentary rock. This shows that the momentum forming them must have come from above, during the impact of an enormous meteorite.

Additional proof for this process is provided by the possibility of artificially reproducing shock cones, even though only on a very small scale - for example, by shooting a shell moving at a velocity of about 100 km/sec from a gas gun into a block of limestone. As a result, very small, but very distinct, shock cones are formed in this block.

It is interesting to note that such formations can be readily observed in fossil meteorite craters, and not in craters of recent origin. This is related to the fact that the intensity of the /12
shock wave decreases inversely proportionally to the sixth power of the distance, and therefore the shock cones are most distinctly formed in those craters where they are piled up as pulverization products. Nevertheless, Chao recently discovered small shock cones on the southern edge of the Arizonskiy crater.

The shock cones made it possible to establish the fact that enormous meteorites fell repeatedly on our planet in the far removed past, forming large craters. The fourteen meteorite craters which are known at the present time pertain, in essence, only to the recent past of the earth. If it is even assumed that one large fall occurs every 10,000 years, then no less than 50,000 gigantic meteorites could fall on the earth during its lifetime. The visible traces of the falls have disappeared long ago, but in several cases indirect evidence remain - in particular, shock cones. The so-called Vrederfort ring exists in South Africa, located near Pretoria. It was apparently formed about 250 billion years ago during the fall of an asteroid having a diameter of about 1.5 km. As a result, a crater was formed having a diameter of almost 50 km and a depth of 15 km, as closely as can be estimated. The explosion which was thus produced was, apparently, a million times stronger than during the eruption of the volcano Krakatoa in 1883, when half of the mountain flew into the air and was disseminated into the atmosphere over the entire terrestrial sphere in the form of a fine dust.

Another product of a shock wave is the superhard form of quartz-koesite. Artificial koesite, which has been prepared in a laboratory, requires a pressure of 20,000 atm, which apparently corresponds to a depth exceeding 60 km. This modification of quartz has also been discovered in several craters, where quartz was the original material. In this connection, it is interesting to note that in meteorite fragments collected around the Arizonskiy crater small granules of diamonds were encountered, which were formed from carbon also at a very high pressure.

It should be noted that the formation of koesite during the impact of meteorites on the ground, as the result of the enormous pressures which are produced, shows that the same mineral is formed also during atomic explosions, in the craters which are thus formed.

Tektites also represent a similar problem; up to the present, their origin remains enigmatic. According to the results obtained by Ehmann (Ref. 13) in 1958, the radioactive isotope of aluminum 26 exists in tektites, and if this is so, then such bodies undoubtedly have a cosmic origin. However, very recently Viste and Anders (Ref. 14) tried to verify this by studying 79 tektites from Australia and Southeast Asia, using the spectrometric method of gamma-gamma agreement. Not in one single case were they able to find any positive traces of aluminum 26. As is indicated by these authors, the negative results which they obtained did not definitively contradict the assumption regarding the cosmic origin of tektites. They assumed that the following alternatives are possible: either the tektites were subjected to bombardment in cosmic space for a comparatively short period of time - for example, less than 10,000 years - or they were initially contained in enormous bodies which could protect them from the direct action of cosmic rays.

In any case, the hypothesis of Urey and Koman regarding the interstellar origin of tektites must be regarded as completely untenable. The hypothesis that tektites belong to the planets of the solar system is extremely improbable, and the hypothesis that they were ejected from the moon - which hypothesis is now upheld by many authors, including Chepmen - is possible. However, this hypothesis encounters several difficulties. In particular, /13
special orbits are required, along which the particles which are ejected from the moon can reach the earth after a comparatively short period of time. In addition, it must be assumed that tektites were not ejected from the lunar surface - where they could be acted upon by cosmic influences - but from a depth of at least

several meters or more. Along with this, if lunar matter were ejected from shallower levels, then there would have to be samples containing aluminum 26 and other similar isotopes, in addition to the normal tektites without cosmogonical isotopes.

In any case, various authors - such as Varnes (Ref. 15) - who do not subscribe to the hypothesis of tektites originating from the moon, all indicate that these bodies are not fragments of larger bodies, that in regions where gigantic meteorites are known to have fallen, forming craters, no tektites are encountered. They also point out that australites have twofold characteristics - initial melting and rapid solidification of the given substance, and then secondary surface treatment, which is apparently related to the tektites passing through the terrestrial atmosphere. It must be noted that other types of tektites do not have this characteristic. Finally, it is pointed out by everyone that the entire form and internal structure, the tensions within the mass, the tension bands - detected by polarization methods - and even the presence of pores within the tektites - all of this points to the fact that such bodies were subjected to rapid melting and cooling.

It is also extremely improbable that, as the result of impacting on the terrestrial surface, a substance could be ejected within the limits of the terrestrial atmosphere, be cooled, and again pass through the atmosphere - forming rather compact knots falling only on definite sections of the earth's sphere. There are no indications that any catastrophic phenomena on the earth are related to the formation of tektites: craters, although far enough away from where they are located, or gigantic floods as the result of enormous asteroidal masses falling into the ocean, or any other similar phenomenon. Therefore, it is more probable that the moon is the origin of tektites.

As is known, tektites have not been found in the USSR. In this connection, it is interesting to note the fact that the geologist G. T. Kravchenko has found small silicate pellets whose form is very reminiscent of congealed drops of glass, sometimes with sharp branches and bubbles inside, which pertain to the quaternary or to the later tertiary period - i.e., they are about a million years old. Do they represent formations which are similar to tektites? I can also point to the cyrillides - to the procession of an entire group of slow bolides, which was observed in Canada on February 9, 1913, which is related to tektites by several authors, for example O'Keefe (Ref. 16).

On the basis of existing data, this process seems to represent earth satellites, which have penetrated the earth's atmosphere after several revolutions and have finally ceased to exist. We can also point out the recent discovery by Kordilevskiy of two earth satellites which have the form of indistinct dark spots. They apparently represent more or less compact meteor clusters which are formed at the distance of the lunar orbit at two libration points, at an angular distance of 60° in front of and behind the moon.

The recent discovery of a carbonaceous type of organic compound in meteorites has caused a great sensation. Thus, for example, Nagi, Meynsheyn, and Kenessi studied the hydrocarbon content in the carbonaceous meteorite Orgueil, and used a mass-spectrograph to compare the spectra of the distilled meteoritic substance with other substances - oil and a different substance from recent deposits. As /14
a result, they came to the following conclusion: "Although this analysis probably does not contain all of the hydrocarbon in the meteorites having high molecular weight, the analysis which we performed shows that the hydrocarbons in the meteorite Orgueil in many respects resemble the products of living organisms in terrestrial deposits.

On the basis of this preliminary study, it can be concluded that living forms existed in other regions of the universe beyond the limits of the earth".

It should be noted that this conclusion, which apparently has no relationship with ideas on the origin of meteorites and the physical properties of the solar system, has encountered criticism from specialists. Professor Bernal quickly opposed this conclusion. Anders opposed this work on the basis of the same material taken from the New York Museum, and voiced several significant objections to it. For example, he pointed out that the agreement between the mass-spectra, indicated by Nagi, was very weak, and that the biogenous material agreed very poorly. He also pointed out that the meteoric substance used could be easily filled with organic admixtures, that carbonaceous chondrites are very porous and readily absorb any changes in the composition of the air - adsorbing particularly readily atmospheric argon, as was pointed out by Shtauffer in 1961. The meteorite Orgueil had remained in the museum about 100 years.

As Anders noted further, if the meteorite Orgueil actually contained hydrocarbons, they would have been broken down after existing for several years in cosmic space due to the bombardment by cosmic rays. In addition, because this meteorite contained sulphur also, at a comparatively low temperature - for example, about 400° C - it can change hydrocarbons significantly, and for this reason their final distribution must differ considerably from the initial distribution. Finally, it is generally known that primary hydrocarbon compounds arise naturally even under conditions of interstellar space, due to which fact comets have an abundance of carbon compounds - as their spectra show. However, no-one will state that any resemblance to organic life can exist in comets due to this fact. In general, it must be stated that the conclusions of Nagi and his co-authors with respect to the existence of living organisms in meteorites are absolutely untenable.

In conclusion, we should note that as the study of meteorites advances, interesting new problems are confronting science, which connect these formations with different aspects of the evolution of the planetary system. Previously, in the first epoch when

science recognized them, meteorites were regarded simply as interesting rarity stones which traveled from space. Their close relationship with physical conditions existing in interplanetary space, primarily with cosmic radiation, has now been clarified. The latter appears in the presence of different isotopes having a short lifetime. The very structure of meteorites clearly indicates how complex were the conditions under which the solar system was formed in the past, when brief radiogenic elements could have an influence. The content of different gases in meteorites also represents a problem which is far from being solved. It is sufficient to point out the discovery of Gerling and Levskiy in 1958 of an unusual abundance of inert gases in the meteorite Staroye Pes'yanoye. Not only was the content of helium and neon much greater than in any meteorite, but also the ratio of isotopes was completely different. These results of Gerling and Levskiy, which were confirmed in 1961 by Shtauffer, as well as similar results by Tseringer, Gertner, /15
and others, show that we have here a problem which is more general in nature than was first assumed.

Due to the complexity and uniqueness of the questions relating to this, a special detailed study must be devoted to the problem of the presence of gases in meteorites and of isotopes existing in them.

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